Cracking the AQ Code

ADEQ Arizona Department of Environmental Quality

Air Quality Forecast Team

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Measuring the World above Us

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A lot is happening above us. Currents of air move about, transporting heat and moisture from place to place, and causing rising and sinking motions in the atmosphere. If you've ever flown in an airplane, then you've entered this world (Figure 1). But why should we care about it? It's simple: what happens up there determines the weather we experience down here, at the ground. In this issue of *Cracking the AQ Code*, we will explore how we are able to measure the meteorological properties of the upper levels of the troposphere (the lowest layer of the atmosphere where weather occurs). We'll then finish with how all of this can matter for air quality in Arizona.

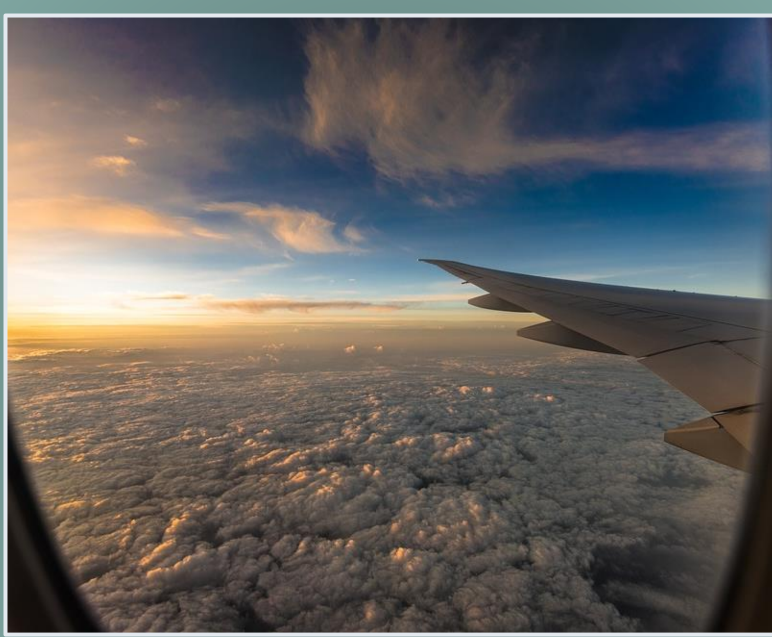

Figure 1: Here is a view from an airplane window. Modern technology, as we will see, has made the "world above us" more accessible than ever. And this benefits air quality forecasting.

About "Cracking the AQ Code"

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In an effort to further ADEQ's mission of protecting and enhancing the public health and environment, the Forecast Team has decided to produce periodic, in-depth articles about various topics related to weather and air quality.

Our hope is that these articles provide you with a better understanding of Arizona's air quality and environment. Together we can strive for a healthier future.

We hope you find them useful!

<u>Upcoming Topics…</u>

- 2017 Air Quality Review

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From the Ground Up

If you were curious about the Earth's atmosphere, how would you get up there? In the 1890s, a French meteorologist by the name of Leon Teisserenc de Bort had a novel idea: use a balloon. De Bort was one of the first scientists to launch unmanned balloons (made of rubber or paper and filled with hydrogen) up into the atmosphere to learn about it, measuring temperature, pressure, and humidity (meteohistory.org). Such balloons are aptly called "weather balloons" (Figure 2). Using weather balloons, De Bort was instrumental in discovering the stratosphere, the layer of the atmosphere above the troposphere (High Altitude Science).

Figure 2. Meteorologists of the U.S. Navy launch a weather balloon off of the back of an aircraft carrier. Weather balloons are often made of an elastic latex material that expands as the balloon gains altitude. The instrument taking all the measurements can be seen below the balloon.

Source: U.S. Navy

Today, weather balloons are not only still around, they are indispensable—and their importance cannot be understated. Modern weather balloons measure pressure, temperature, humidity, and wind speed/direction up through the atmosphere and then transmit that information back down to the ground. Twice every day, weather balloons are launched, simultaneously, from about 900 locations around the world (Figure 3); the launch times correspond to 5:00 AM and 5:00 PM Arizona time (NWS). This is a global, coordinated effort to capture a 3D "snapshot" of the atmosphere (High Altitude Science). All of this data is then used to diagnose the current state of the atmosphere for weather forecasting (available in what meteorologists call "upper-air" maps; see Figure 7 for an example) and plays an integral part in initializing global weather forecast models (NWS).

Want to learn more about other weather and air quality topics in Arizona?

Click to explore our full *Cracking the AQ Code* archive!

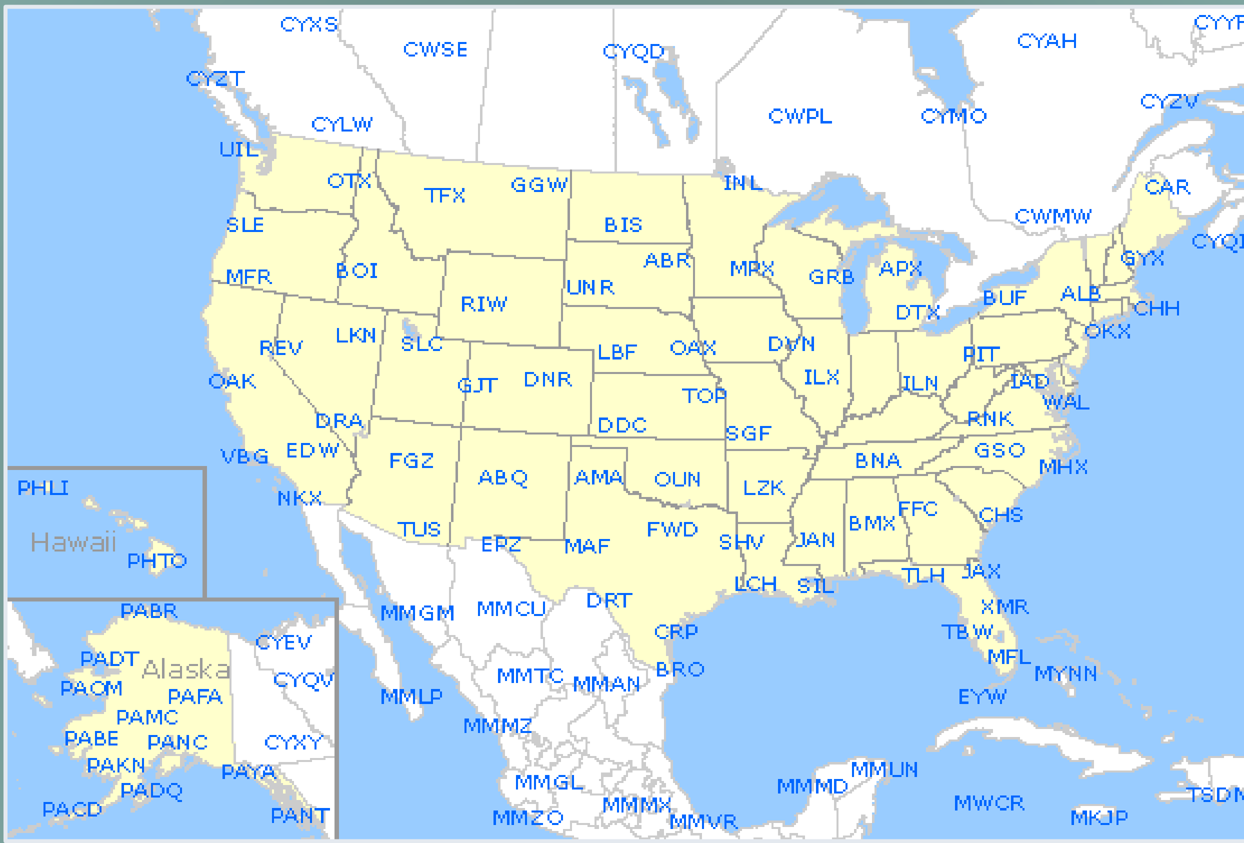

Figure 3. A map showing all of the locations in the North America where weather balloons are launched twice daily. Each station has its own three or four-letter identifier.

Source: UCAR

In Arizona, weather balloons are launched from Flagstaff and Tucson (Figure 4) twice daily. For Phoenix, however, weather balloons are usually only launched during the monsoon season. Of course, weather balloons can be launched at any time if meteorologists believe they will help forecasting in a complex weather situation. On occasion, the U.S. Army Yuma Proving Grounds in Yuma, AZ will launch its own weather balloons for its operations. This data is made available to assist in weather forecasting.

From Space Looking Down

Another way to get a glimpse into the upper levels of the atmosphere is by peering down from above. Modern scientists achieve this view using satellites, a tool that meteorologists in Leon Teisserenc de Bort's time probably couldn't have imagined. In a previous issue, we explored the three main types of satellite imagery: *visible, infrared, and water vapor*. Each type helps us to track and monitor weather systems, which depend on the flow in the upper levels of the troposphere. For instance, water vapor imagery reveals atmospheric flow by detecting the movement of water vapor in the upper levels of the troposphere (Figure 5). In all, satellite imagery helps support data collected from weather balloons.

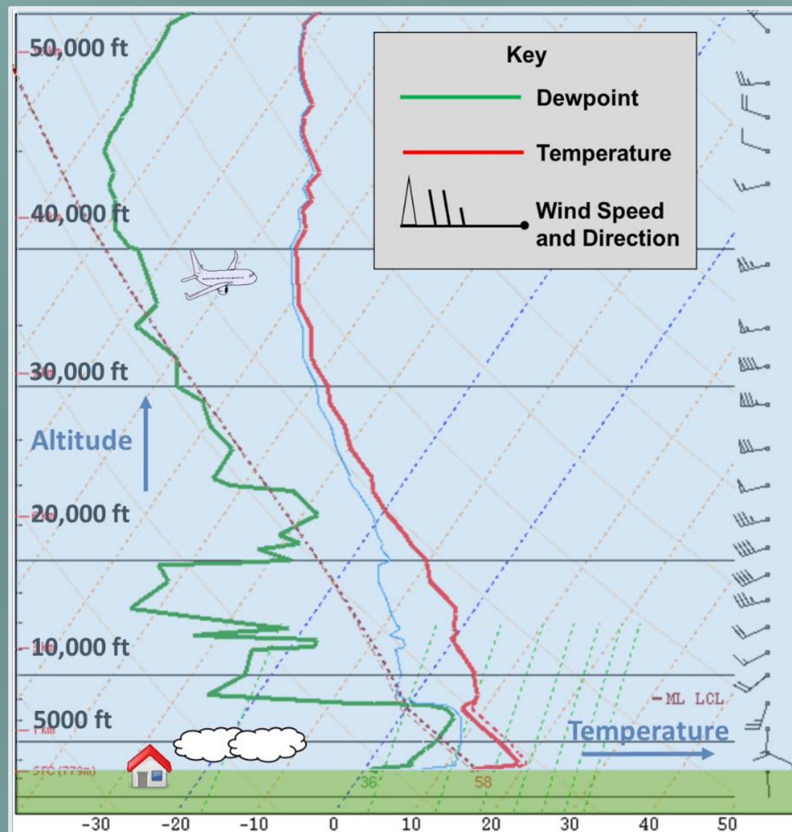

Figure 4. This diagram shows meteorological data collected by a weather balloon launched from Tucson, AZ on November 2, 2017. Observations of temperature (red line) and dewpoint (green line) are in Celsius; wind speed/direction (black arrows along the right side) is in knots.

Source: Storm Prediction Center

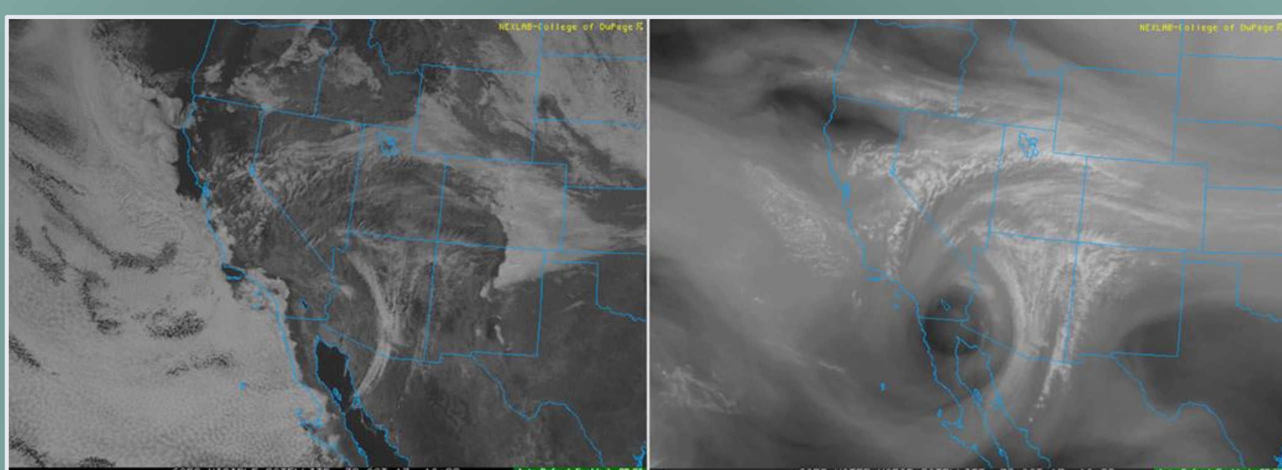

Figure 5. Here we have examples of visible (left) and water vapor (right) satellite images, taken over the U.S. Southwest at 11:00 AM Arizona time, October 30, 2017. The water vapor image reveals a circulation in the upper levels of the atmosphere that cannot be seen by the naked eye.

Source: College of DuPage Weather

From the Air

Lastly, we can learn about the upper levels of the atmosphere from airplanes flying through them. Pilots often report weather conditions they encounter while flying, particularly hazardous conditions, such as turbulence and icing (ice forming on the airplane) (Figure 6). The information gathered in this way is useful to other pilots so they can avoid known hazards in the air ([NWS](NWS)). Also, many commercial airplanes have automated weather observing and reporting systems onboard that measure temperature, wind speed/direction, pressure altitude, and turbulence ([WMO](WMO)). Such data is very similar to the kind of data that weather balloons provide.

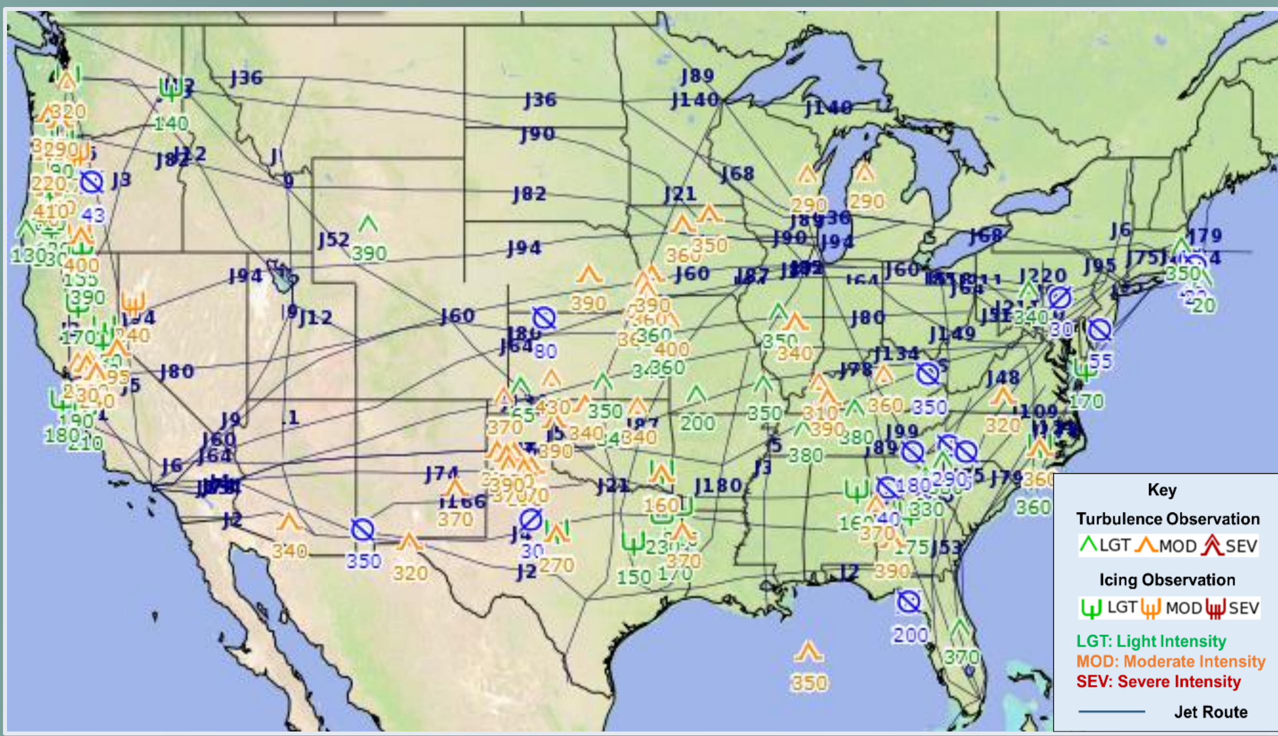

Figure 6. This map shows aircraft and pilot reports around the U.S., along with the main jet routes. It includes reports of hazards such as turbulence and icing and their severity. The time of this map is 2:24 PM Arizona time on November 8, 2017. The cluster of turbulence and icing icons in the Northwest are the result of an incoming low pressure trough in the upper levels of the atmosphere.

Source: Aviation Weather Center

Now that we have seen how we can observe and measure "the world above us," let's use it to help us understand a dust event that affected Phoenix on October 20-21, 2017.

Phoenix PM_{10} Health Standard Exceedance

On October 19, 2017, and through the night into the next day, a strong wave of low pressure in the upper levels of the atmosphere advanced over the West Coast states from the Pacific Ocean. The two "upper-air" maps in Figure 7 (derived, in part, from weather balloon data) show the wave's movement over the West Coast. Atmospheric winds flow parallel to the black lines and winds are strongest where the black lines are tightly packed.

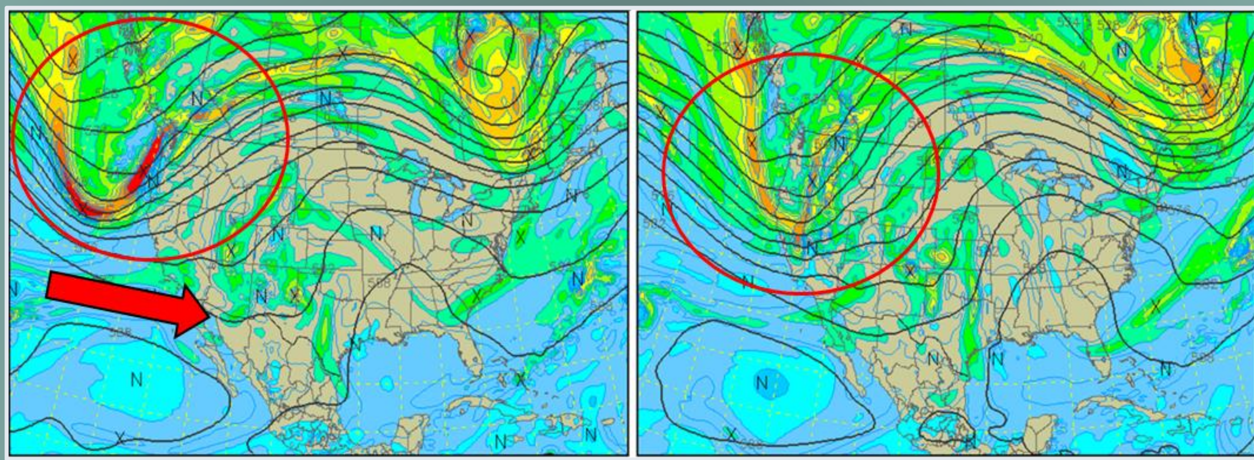

Figure 7. Here are two "upper-air" maps showing the movement of a low pressure wave (circled in red) from the Pacific Ocean over the Northwest U.S. The maps represent the state of the atmosphere at 5:00 PM (Arizona time) on October 19 (left) and the same time on October 20 (right); the red arrow shows the movement of the system.

Source: UCAR Image Archive

Systems like this one are of interest because of the strong, atmospheric flow they bring over the region, generally out of the west. On occasion, this westerly flow can line up directly over southern California. Since the terrain east of southern California's coastal mountains is flat and often arid, strong winds are able to traverse it, pick up dust, and transport the dust into Arizona. And this is exactly what happened on October 20-21, 2017. Figure 8 shows how dust progressed eastward due to strong winds on October 20 from El Centro, California, to Yuma, Arizona, and finally to Phoenix around midnight the next day.

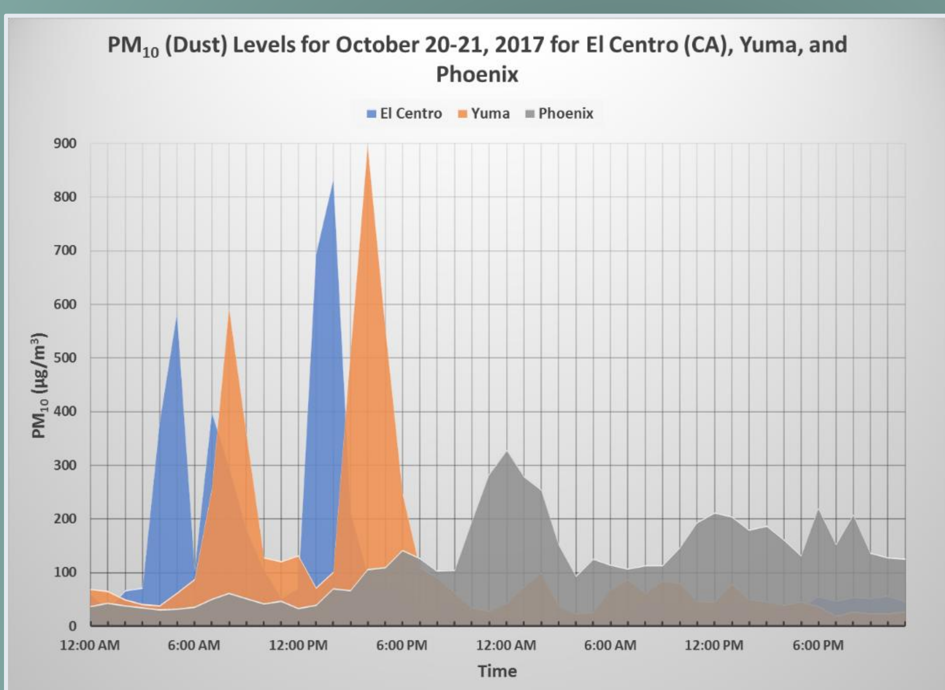

Figure 8. This graph shows PM_{10} (dust) concentrations observed in El Centro, CA (blue), Yuma (orange), and Phoenix (gray) on October 20-21, 2017.

Source: Imperial County Air Pollution Control District, Maricopa County Air Quality Department, Arizona Department of Environmental Quality (ADEQ)

Whenever El Centro experienced high levels of dust, Yuma saw high dust levels soon after, which happened twice on the 20th. Such a pattern makes sense, considering Yuma's close proximity to El Centro. However, Phoenix didn't see its highest dust levels until closer to midnight on the 21st. Also, dust levels remained elevated in Phoenix throughout the rest of the next day (see Figure 10), whereas dust levels dropped more rapidly in El Centro and Yuma the previous day.

The fact that Phoenix saw dust much later than Yuma shows that it took time for the dust (and gusty winds) to reach Phoenix. Also, the fact that Phoenix's dust levels weren't as high as El Centro's and Yuma's reveals that the dust was becoming less concentrated as it moved away from California. Figure 9 gives a good visual of how the dust spread out from southeast California into southwest and central Arizona between the 20th and 21st of October.

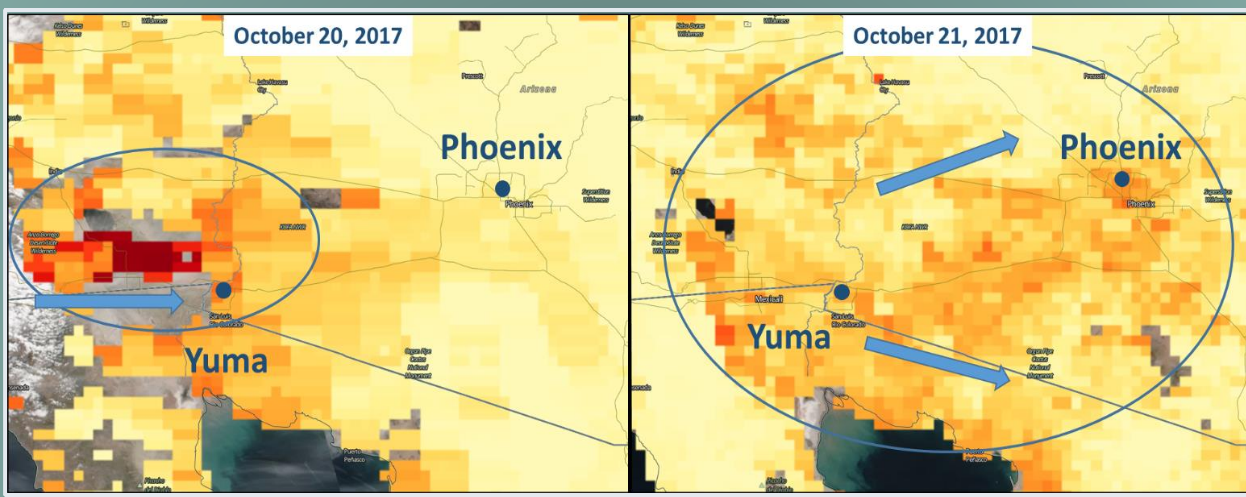

Figure 9. One useful satellite tool is "Aerosol Optical Depth," which is a measurement of the amount of particles in the atmosphere over a given location. Here are two satellite images showing Aerosol Optical Depth over southeast California and southwest and central Arizona for October 20-21, 2017. On the 20th, a high concentration of particles in the atmosphere (dust) can be clearly seen over southeast California within the blue circle (dark orange, red, and brown colors). In the second image depicting the next day, the dust can be seen spread out throughout southwest and central Arizona (dark orange colors). The blue arrows denote the motion of the dust.

Source: NASA Worldview satellite imagery tool

In the morning on October 21, Phoenix residents woke up to a haze enveloping the whole Valley as dust lingered over central Arizona (Figure 10). When it was all said and done, four PM_{10} (dust) monitors—Central Phoenix, Dysart, South Scottsdale, and Zuni Hills—exceeded the PM_{10} standard set by the Environmental Protection Agency on October 21. Additionally, seven more PM_{10} monitors around the Valley nearly exceeded the standard (Health Watch criteria). By the next day, the haze had cleared out and dust around the Valley was back to normal levels.

In all, a strong wave of low pressure in the upper-levels of the atmosphere was to blame for adverse air quality in Phoenix, AZ.

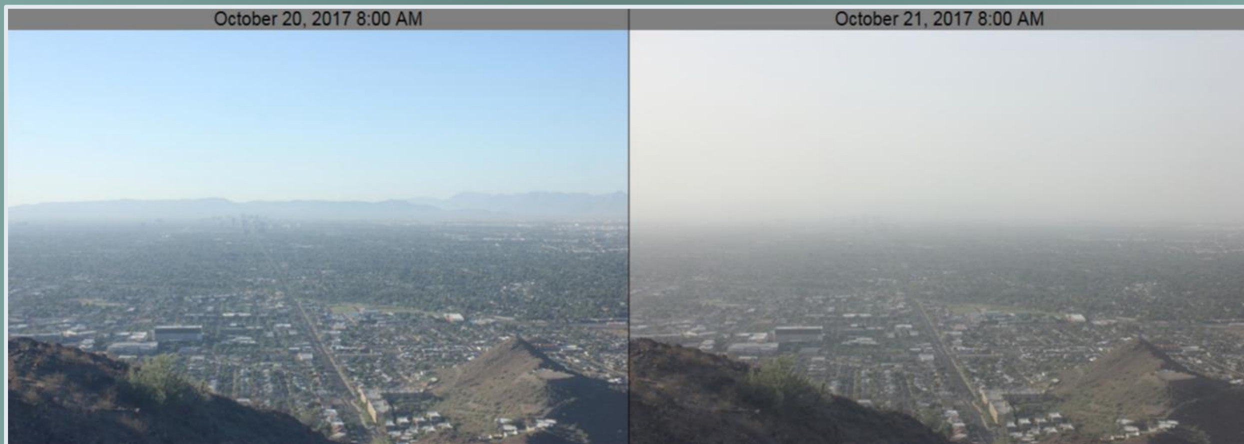

Figure 10. This is a side-by-side comparison of the visibility in the Valley at 8:00 AM on October 20 (left) and October 21 (right). Both pictures were taken by one of ADEQ's webcams on North Mountain looking south toward South Mountain. Central Avenue can be seen in the center of the images. The haze on the 21st totally obscures the view of South Mountain.

Source: ADEQ

More Accessible Than Ever

In this day and age, we have tools that help us see what happens high up in the atmosphere. Some of those tools are sophisticated, such as satellites. Others are simple, like the weather balloon, which has been around for over a century. But we also have computers, which help to put all of that data together and give us a 3D picture of the earth's atmosphere. As a result, the upper-levels of the troposphere—the world above us—is more accessible to us than it has ever been. And this benefits air quality forecasting.

We hope you enjoyed learning about how we can get a glimpse into the "world above us" and what it can mean for both weather and air quality here in Arizona!

Sincerely,

The ADEQ Forecast Team

ForecastTeam@azdeq.gov

If you haven't already, click HERE to start receiving your Daily Air Quality Forecasts (Phoenix, Yuma, Nogales)

In case you missed the previous Issues…

June 2017: [Patterns in Phoenix Air Pollution]
July 2017: [Tools of the Air Quality Forecasting Trade Part 4: Weather Forecast Models]
September 2017: [Organized Thunderstorms in Arizona]
October 2017: [Weather Chaos: Model Uncertainty]
For Full Archive (2015-2017): [Click Here]

Here's a look at what we'll be discussing in the near future…

-2017 Air Quality Review

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Air Quality Forecast Team

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